Fishery Data Series No. 99-10

Escapement of Chinook Salmon in the Unalakleet River in 1998

Klaus G. Wuttig

June 1999

Alaska Department of Fish and Game

Division of Sport Fish

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd

Spell out acre and ton.

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s

Spell out year, month, and week.

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	\$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

FISHERY DATA SERIES NO. 99-10

ESCAPEMENT OF CHINOOK SALMON IN THE UNALAKLEET RIVER IN 1998

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

During 1998, radio telemetry in conjunction with a counting tower was used to estimate escapement of adult chinook salmon *Oncorhynchus tshawytscha* in the Unalakleet River drainage, Alaska. Moreover, radio telemetry was used to investigate the interannual (1997-1998) variation found in the proportion of the escapement which migrated up the North River, a tributary of the Unalakleet River. Escapement estimates were obtained by expanding the estimated passage of fish from a counting tower located on the North River by the proportion of chinook salmon that migrated up the river. The proportion of chinook salmon migrating up the North River was determined from the movements of radio-tagged chinook salmon recorded by a remote tracking station placed at the confluence of the Unalakleet and North rivers and through aerial surveys. A total of 165 chinook salmon were esophageally implanted with pulse-encoded transmitters. Of these fish, 149 migrated upstream and were successfully located, 12 were lost in the commercial and sport fisheries, and four remained unaccounted. The proportion of the chinook salmon escapement migrating up the North River in 1997 and 1998 was 37.2% (SE = 4.0) and 40.1% (SE = 4.0), respectively. Estimated 1997 and 1998 escapements for the entire Unalakleet River drainage were 11,204 (SE = 1,467) and 5,220 (SE = 691) chinook salmon, respectively. Chinook salmon carcasses were collected in the Unalakleet River drainage to estimate age-sex-length compositions. Females comprised 0.50 (SE = 0.04) of the sample. Age class 1.3 composed the largest proportion of the females sampled, while age class 1.3 composed the largest proportion of the males sampled.

Key words: chinook salmon, *Oncorhynchus tshawytscha,* Unalakleet River, North River, radio telemetry, counting tower, abundance, escapement, carcass survey, age-sex-length compositions

INTRODUCTION

The Unalakleet River is located north of the mouth of the Yukon River in Norton Sound (Figure 1). The Unalakleet River and its tributaries drain an area approximately 2,700 square km as it flows southwesterly through the Nulato Hills (Sloan et al. 1986). The Unalakleet River supports an important chinook salmon *Oncorhynchus tshawytscha* run which sustains the largest subsistence, commercial, and sport harvests in Norton Sound.

Since 1989, annual chinook salmon sport harvests have averaged around 250 chinook salmon, while annual catches have averaged about 460 fish (Table 1). Angler effort on the Unalakleet River has been estimated to range from 1,700 to 5,500 angler days annually since 1989, however, only a part of this is directed toward chinook salmon (Mills 1990-1994, Howe et al. 1995-1998). Other sport-caught species in the drainage include pink salmon *O. gorbuscha*, chum salmon *O. keta*, coho salmon *O. kisutch*, Dolly Varden *Salvelinus malma*, and Arctic grayling *Thymallus arcticus signifier*. Commercial harvests of chinook salmon have ranged from 2,218 to 12,621 since 1982. Commercial catches have averaged 5,003 fish over the last 10 years (Table 1), and the 1995 harvest of 9,067 was the second highest on record (Rob 1998b). Despite the important sport and commercial fisheries, no escapement goals for chinook salmon have been established in the Unalakleet River and there are no harvest guidelines. The lack of escapement goals and harvest guidelines is largely due to unsuccessful attempts at estimating the chinook salmon escapement.

Historically, the Commercial Fisheries Division (CFD) has assessed the Unalakleet River chinook salmon escapement, in part, through aerial surveys (Table 2). However, problems with water clarity and channel morphometry have limited the ability of CFD to adequately assess salmon spawning escapements in the Unalakleet River using aerial survey techniques. This is in contrast to the North and Old Woman rivers which are smaller and tend to run more clear (Figure 1). Existing aerial survey data suggested that about half of the escapement of chinook salmon

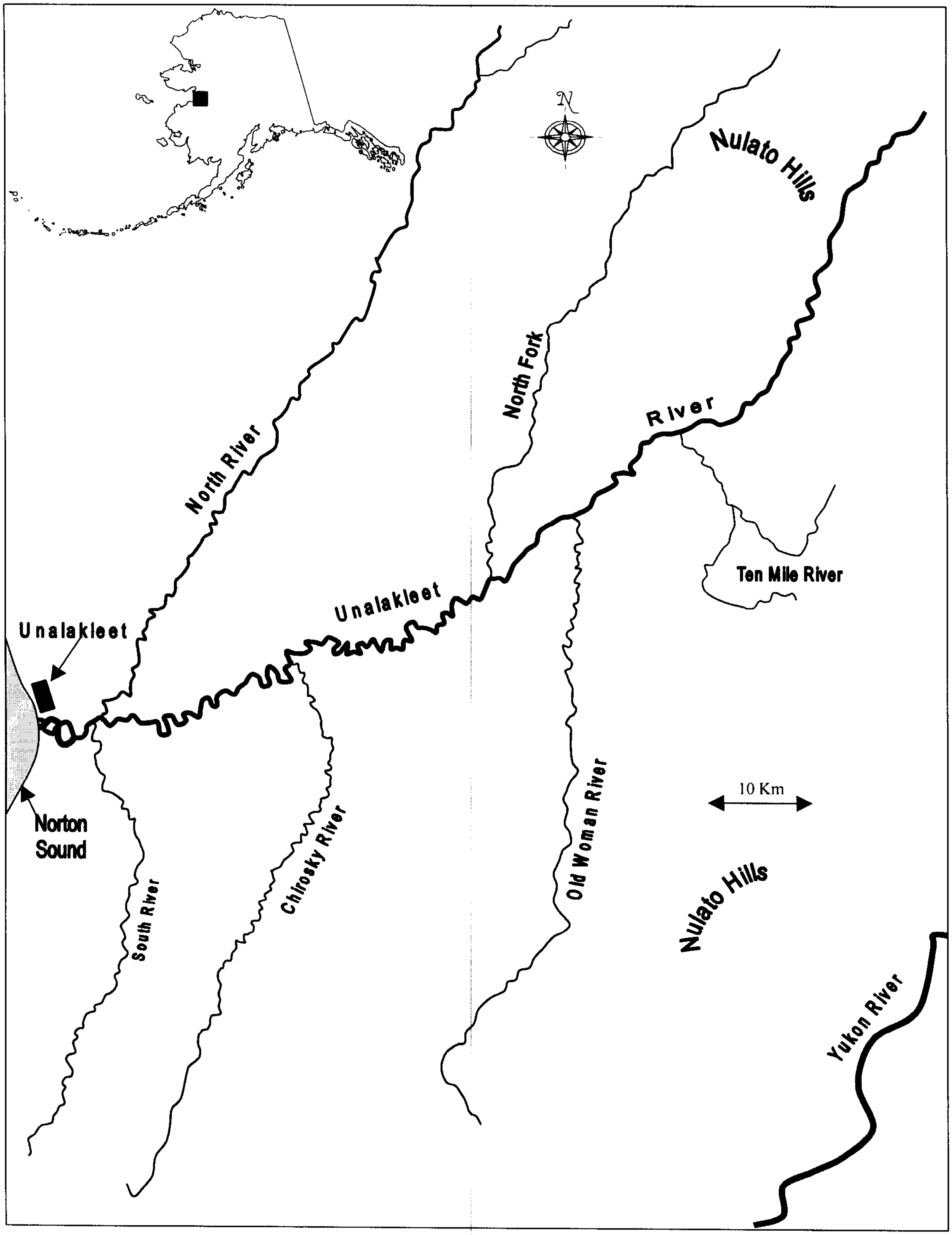

Figure 1. -Unalakleet River drainage.

Table 1.-Unalakleet River chinook salmon commercial harvests, sport harvests and catches, test net catches, and North River tower counts, 1982-1997.

Year	North River Tower Count[a]	Sport Catch[b]	Sport Harvest[b]	Commercial Harvest[c]	Commercial Catch CPUE[c]	Test Net Catches[c]	Test net CPUE[c]
1982				3,768	1.65	22	2.74
1983				7,022	2.65	18	2.55
1984	2,844	---	39	6,804	4.44	41	3.63
1985	1,426	---	179	12,621	4.75	171	9.93
1986	1,613	---	850	4,494	1.98	49	2.19
1987		---	---	3,246	2.77	42	2.23
1988		---	---	2,218	1.64	13	0.67
1989		---	49	4,402	2.74	45	2.03
1990		361	276	5,998	3.64	41	1.82
1991		375	296	4,534	2.63	33	1.71
1992		476	117	3,402	1.72	23	1.18
1993		2,340	382	5,944	4.08	91	4.61
1994		517	379	4,400	5.07	35	1.53
1995		588	259	7,617	2.15	85	4.79
1996	1,197	431	176	3,644	2.84	139	6.53
1997	4,185	1,898	609	9,067	7.67	193	8.52

[a] North River tower counts from Rob 1998a.

[b] Sport fish catch and harvest from Mills 1983-1994; Howe et al. 1995-1998.

[c] Commercial harvest and CPUE, and test net catch and CPUE from Rob 1998b.

Table 2.-Summary of aerial survey counts for the Unalakleet River drainage, 1980-1998.

	North River		Old Woman River		Unalakleet River	
Year	Count	Remarks	Count	Remarks	Count	Remarks
1980	61	A	25		-	
1981	31	A	26		3	
1982	4	A	-		-	
1983	347	A	-		-	
1984	51	A	-		-	
1985	873	B	202	F	400	?
1986	-		-		367	?
1987	432	B	130		341	J
1988	202	C	311	G	923	K
1989	-				-	
1990	231	D	211	H	484	K
1991	656	C	389	I	1244	K
1992	329	C	-		-	
1993	900	E	387	I	253	K
1994	-		-		-	
1995	622	C	424	I	532	K
1996	106	C	55	I		
1997	1,585	C	246	I	984	K
1998	591	C	312	I	739	K

Data from C. Lean, ADF&G, Nome, personal communication, 1998.

<u>Remarks</u>

A Area surveyed not known.
B Mouth to headwaters.
C Mouth to river mi 40 (Sunquist).
D Mouth to river mi 50.
E Mouth to river mi 30.
F Mouth to river mi 15.
G Mouth to river mi 40.
H Mouth to river mi 30.
I Mouth to river mi 25 (Chirosky pass).
J River mi 37 (mink farm) to above Old Woman.
K River mi 45 (Auley's cabin) to Ten Mile River.
? River section unknown.

spawn in the North River, but this is thought to be biased high because of higher detectability in the North River's clear water (Table 2).

In addition to aerial surveys, CFD uses a standardized (since 1981) test net (5.875 in stretch measure gillnet) project as an escapement index, and data from commercial catches to manage the chinook salmon fishery (Rob 1998b). Commercial catches, catch per unit effort (CPUE) for the commercial harvest (1.64 to 7.76), and test net catch (0.67 to 9.93) show that the chinook salmon escapements are variable (Table 1). Furthermore, commercial harvests may include fish from other stocks such as the Yukon or Shaktoolik rivers and may not provide dependable indices of run strength to the Unalakleet River.

Other methods implemented to assess salmon escapement have included sonar, inseason subsistence surveys, and counting towers (Rob 1998b). Hydroacoustic counting techniques were unsuccessful in three prior years (Rob 1998b). Estimates of subsistence harvests are limited and were 3,026 and 2,894 for 1995 and 1996, respectively (Bue et al. 1996 and 1997). Chinook salmon have been successfully counted on the North River during 1984 - 1986, and 1996-1998 (Table 1).

In 1997, the first successful chinook salmon escapement (11,204 fish; SE = 1,467) was estimated for the Unalakleet River drainage (Wuttig 1998). This estimate was attained by expanding the North River counting tower escapement estimate by the estimated inverse proportion of fish that migrated up the North River. This proportion was determined through the use of radio telemetry, and it was estimated that 37.2% (SE = 4.0) and 62.8% (SE = 4.0) migrated up the North and Unalakleet rivers, respectively (Wuttig 1998).

This was the second year of a project designed to estimate the abundance of chinook salmon escaping into the Unalakleet River and to investigate the interannual variability found in the proportion of the Unalakleet River chinook salmon returns that migrate up the North River. The specific objectives of the Unalakleet River chinook salmon project in 1998 were to:

1) estimate the proportions of the chinook salmon escapement migrating up the North River, the mainstem of the Unalakleet River, the Chirosky River, the North Fork of the Unalakleet River, and the Old Woman River through the use of radio telemetry;
2) test the hypothesis that the proportions of the Unalakleet River chinook salmon escapement migrating up the North River in 1997 and 1998 are equal;
3) estimate the abundance of chinook salmon escaping into the Unalakleet River drainage by proportional expansion of the North River tower count estimate; and,
4) estimate the age, size, and sex composition of the chinook salmon escapement into the Unalakleet River drainage in 1998.

METHODS

To estimate the proportions of the chinook salmon escapement migrating up the North River and the Unalakleet River and its tributaries, radio tags were implanted in chinook salmon downstream from the mouth of the North River. A remote data logger and receiver placed at the mouth of the North River recorded the passage of radio-tagged salmon as they migrated either up the North River or up the mainstem of the Unalakleet River. Salmon distributions were further determined using aerial and boat tracking. A counting tower was established on the North River by the Kawarek Corporation Fisheries Group to estimate the number of chinook salmon migrating up the river. The entire Unalakleet River chinook salmon escapement was then estimated by expanding the North River tower count by the inverse proportion of chinook salmon swimming up the North River. Chinook salmon carcasses were collected to determine age-sex-length compositions.

CHINOOK SALMON CAPTURE, HANDLING, AND TELEMETRY

Chinook salmon were captured at a single site approximately 5 km upstream from the mouth of the Unalakleet River and 3 km downstream of the mouth of the North River from 17 June to 15 July (Figure 2). This tagging location was upstream from the majority of the subsistence effort and downstream from the majority of the sport fishing effort. Fish were captured by setnetting and driftnetting, both of which used the same gillnet (20.3 cm stretch mesh, 56.0 m long, and 4.0 m deep).

When setnetting, the gillnet was set across a shallow channel (approximately 75-m wide and ≤ 2 m deep) utilized by migrating salmon. The net was set perpendicular to shore with one end secured to shore and the other end (lead-line and float-line) fixed to the stream bottom using 25 lb boat anchors. The net blocked approximately two-thirds of the channel, to allow for boat passage. The net was set so that it angled downstream (lead-line upstream of the float-line) such that a fish would swim under and then into the net. A two-man crew in a 16-ft boat waited at the offshore end of the net to deter fish from migrating around the end of the net and to watch for entangled fish. Once a chinook salmon was entangled, the boat was positioned downstream of the fish, the net was pulled over the bow, and the salmon was placed into a holding tub and removed from the net. As in 1997, attempts were made to fish the setnet for 5-h/d, 4-h prior to and 1-h after high tide, when catch rates tended to be greater. During this time the incoming tide slowed the water velocity enough so that the net would not be washed downstream. However, in 1998 higher than average discharges for the Unalakleet River did not always permit a gillnet to be set across the channel due to swifter currents. Only during periods of greater tide differentials in conjunction with lesser flows was setnetting permissible. Therefore, when not setnetting chinook salmon were captured by drifting the same down a reach of the river (approx. 300 m) encompassing the setnet site.

When driftnetting, the gillnet was deployed from a 16-ft boat approximately 100 m above the setnet site. The net was drifted down the channel used by the migrating chinook, through the setnet site, and pulled from the water approximately 200 m below the setnet site if no fish were netted. This particular reach was found to contain the least amount of snags (rocks and woody debris; Figure 2). When a chinook salmon was captured the net was immediately pulled in and the fish was disentangled. Drift time was monitored with a stopwatch, starting as the net first entered the water and stopping after the entire gillnet was pulled into the boat. During most sampling days a combination of both setnetting and gillnetting was conducted such that the gillnet would fish for the same duration each sampling day in order to standardize fishing effort. It was assumed that gillnetting and driftnetting had equal probability of capture. However, variable catch rates and snags precluded sampling for the same duration each day. High catches resulted in less soak-time due to the handling of more fish, and snags often resulted in lengthy repairs to the net before it could be deployed again that day.

Once captured, the chinook salmon were placed into a tagging cradle submerged in a trough of water. Radio tags were inserted through the esophagus and into the upper stomach (esophageal implants) using a 45-cm plastic tube with a diameter equal to that of the radio tags. The end of

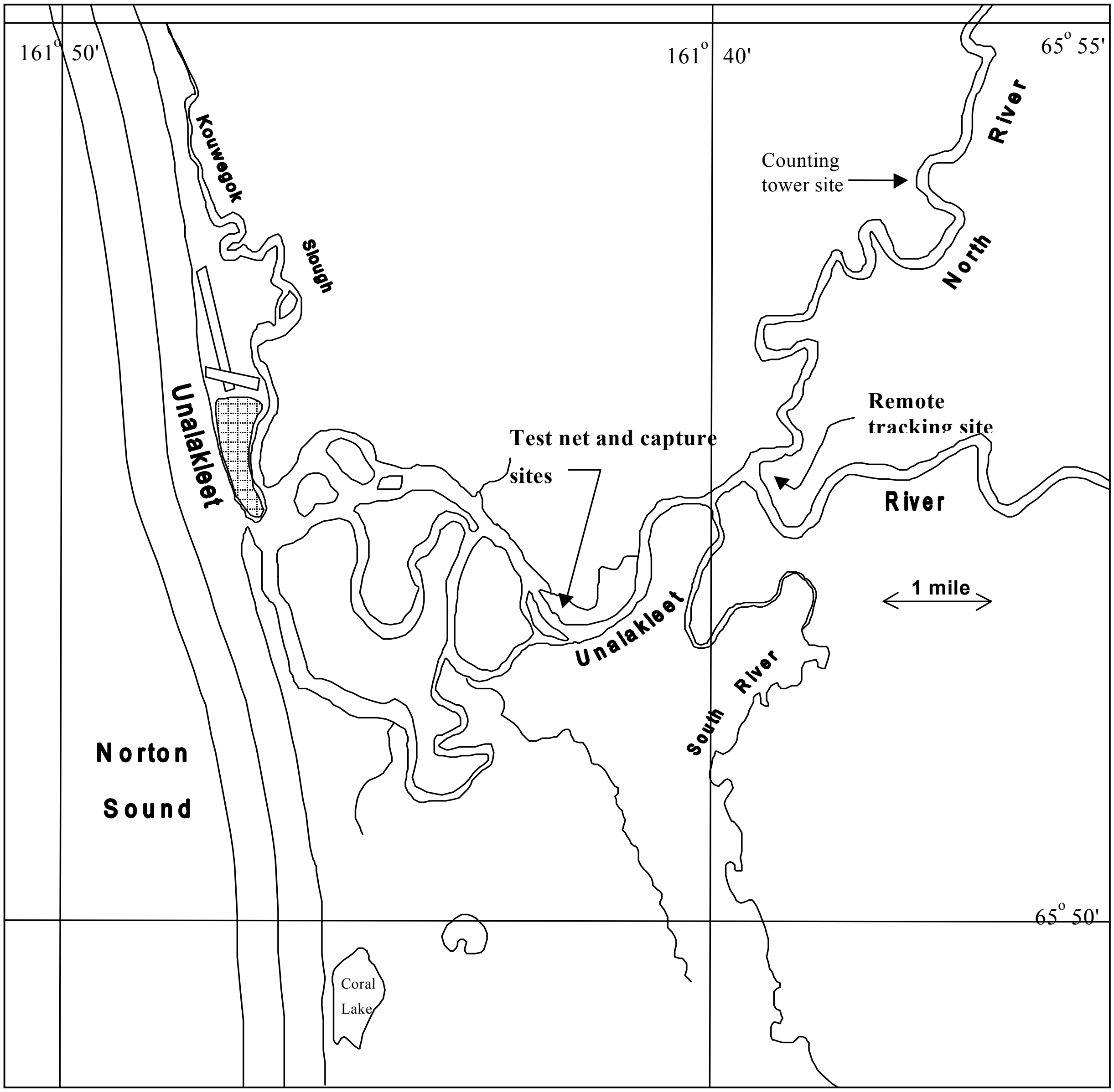

Figure 2.-Unalakleet River capture, test net, remote tracking station, and North River counting tower sites.

the plastic tube was slit lengthwise allowing for the antenna end of the transmitter to be seated into the tube and held in place by friction. The transmitter was pushed through the esophagus such that the antenna end was seated 0.5 cm beyond the base of the pectoral fin. A second tube was slid down the inside of the first tube to unseat the radio transmitter.

Attempts were made to distribute the radio-tags proportional to run strength by standardizing fishing effort. To account for the variation in effort for days when less than 5-h of effort was attained, the daily catches were normalized. CPUE for each day was calculated (catch per hour) and then expanded to 5-h of effort for those days when less than 5-h of soak time was attained. Initially, every other fish captured was implanted with a radio tag. As run intensity varied, every fish to every third fish captured was tagged to ensure that tags were distributed over the entire run. A weighted proportion of fish migrating up the North River was calculated and compared to the simple proportion migrating up the North River. Dissimilar estimates would imply that tags were not distributed proportional to run strength. The simple proportion was calculated as:

$$\hat{P}_N = \frac{n}{N} \tag{1}$$

with variance

$$V(\hat{P}_N) = \frac{\hat{P}_N(1-\hat{P}_N)}{(N-1)}. \tag{2}$$

The weighted proportion was calculated as:

$$P_w = \sum \frac{C_i * P_i}{\sum C_i}, \tag{3}$$

$$P_i = \frac{a_i}{c_i},$$

where:

$\hat{P}_N$ = proportion of radio-tagged chinook salmon which migrated up the North River;

n = number of radio-tagged chinook salmon located in the North River;

N = total number of radio-tagged chinook salmon located above mouth of North River;

P_w = weighted proportion of chinook salmon which migrated up the North River;

C_i = expanded 5-h catch on day i;

P_i = proportion of salmon fitted with radio tags that were later located in the North River;

a_i = number of chinook salmon tagged on day i located in North River; and,

c_i = number of chinook salmon tagged on day i that were located above mouth of North River.

All chinook salmon captured were measured to the nearest 5 mm (mid-eye to fork-of-tail) and data were recorded on mark-sense forms. Three scales were removed from each fish and placed on gum cards for age determination. Sex was determined from external characteristics. All chinook salmon captured received an individually-numbered jaw tag (Evenson 1996). The entire handling process required approximately 2 min per fish and was done without the use of anesthesia. After handling, chinook salmon were taken upstream and placed into quiet backwater areas for recovery.

All fish received a model five pulse encoded transmitter made by ATS (Advanced Telemetry Systems, Isanti, MN). The transmitters were 5.5 cm long, 1.9 cm in diameter, weighed 18 g, and had a 30.0-cm external whip antenna. Maximum battery life was about four months. Each radio tag was identified by its frequency and encoded pulse pattern. Fifteen frequencies spaced approximately 20 kHz apart in the 150-151 MHz range with 10 encoded pulse patterns per frequency were used for a total of 150 uniquely identifiable tags. Five additional tags were deployed which had a frequency and code that was identical to five of the 150 identifiable tags. These duplicate tags were deployed a minimum of two weeks apart to avoid two fish with the same frequency and code passing the remote tracking station simultaneously. Ten radio tags were recovered from the commercial fishery and were redeployed for a total of 165 radio tags implanted.

Migrating radio-tagged fish were tracked and recorded as going up either the North River or the mainstem of the Unalakleet River using a remote tracking station. The station was comprised of integrated components: a marine deep cycle battery, an ATS Model 5041 Data Collection Computer (DCC II), an ATS Model 4000 receiver, and two Yagi antennas. The receiver and DCC were used to detect, identify, and record the radio tags. The station was placed at the confluence of the North and the Unalakleet rivers with an elevated (3 m) Yagi antenna aimed up each river. The receiver and DCC were programmed to scan through the 15 frequencies at 3-s intervals on each antenna. If no fish were detected, the DCC and receiver were able to cycle through all 150 tags in a period of 1.5 min (15 frequencies x 3 s per frequency x two antennas). This relatively short cycle period minimized the chance that a radio-tagged fish could swim past the receiver site without being detected. If a tag was detected the program would pause for 5 s to record the tag identity, time, signal strength, and antenna number (corresponding to the river). It was also possible that 10 coded tags of a single frequency could pass the receiver at the same time, and that some transmitters might not be identified. To minimize the chance of this occurring, the order of the tag frequencies implanted in the fish were rotated through the frequency sequence and repeated until all tags were used.

The distribution of radio-tagged chinook salmon throughout the Unalakleet River drainage was further determined by aerial tracking from small aircraft after all fish had moved upstream. Radio tracking flights were conducted on 15 and 17 July, and 3 August. The North River, the mainstem of the Unalakleet River, the Chirosky River, the North Fork of the Unalakleet River, the Ten Mile River, and the Old Woman River were all surveyed. Total flight time was approximately 15-h.

Aerial surveys were the primary method used to determine which river the radio-tagged salmon migrated up due to complications with the remote tracking station. Prior to 9 July, the signal strengths from the respective antennas recorded by the data logger could not be discriminated. Therefore, the migration pattern, or the river a radio-tagged fish swam up, could not be determined. Furthermore, the remote tracking station's internal clock had malfunctioned and one could not discern the timing of the migration pattern with any certainty. After 10 July, a new data logger was installed and the remote tracking station functioned properly. The location of radio-tagged fish found near the mouth of the North River using aerial tracking were confirmed using boat surveys to ensure that the location of the fish as being in either the Unalakleet or North rivers was accurate.

TOWER COUNTS

Escapements of chinook salmon and the other species of salmon returning to the North River were estimated by counting fish as they passed beneath an elevated counting site. The Kawarek Corporation fisheries group under the advice of CFD operated the counting tower. A counting tower, diversion weir, flash panel, and campsite were constructed on the north side of the North River approximately three river miles upstream from its confluence with the Unalakleet River (Figure 2). Counting was conducted from 15 June through 12 August. From 15 June through 3 August water clarity remained good during the chinook salmon run and visibility was sufficient to accurately count all passing fish. From 3 to 8 August, turbidity from high waters precluded counting operations.

Three persons were assigned to conduct counts. The sampling schedule was set up such that each sampling day was divided into three 8-h shifts to cover the 24-hour day. Counts were conducted for the first half of each hour during each 8-h shift. Shifts I, II, and III started at and ended at 00:00 - 7:59, 08:00 - 15:59, and 16:00 - 23:29, respectively (Appendix A). Shifts not counted were staggered so that a minimum of two shifts were counted each day. Scheduling conflicts with the tower personnel resulted in some deviation from the desired sampling schedule.

ABUNDANCE ESTIMATOR: NORTH RIVER

Estimates of abundance were stratified by day. Abundance estimates were considered a two-stage direct expansion where the first stage is a shift within an 8-h day and the second stage is 30-min counting periods within a shift. The shift stage was considered random and the 30-min counting period was considered systematic.

The number of salmon to pass by the tower per day was estimated:

$$\hat{N}_h = \overline{Y}_h M_h \tag{4}$$

$$\hat{V}\left[\hat{N}_h\right] = \left(1 - f_{1h}\right) D_h^2 \frac{s_{1h}^2}{d_h} + f_{1h}^{-1} \sum_{i=1}^{d_h} \left[M_{hi}^2 \left(1 - f_{2di}\right) \frac{s_{2di}^2}{m_{di}} \right] \tag{5}$$

where:

$$\overline{Y} = \frac{\sum_{j=1}^{m_{dij}} Y_{dji}}{m_{di}} \tag{6}$$

$$s_{1d}^2 = \frac{\sum_{i=1}^{h_d} \left(Y_{di} - \overline{Y}_d\right)^2}{h_d - 1} \tag{7}$$

$$s_{2di}^2 = \frac{\sum_{j=2}^{m_{di}} \left(y_{dij} - y_{dij-1}\right)^2}{2\left(m_{di-1}\right)} \tag{8}$$

$$f_{1d} = \frac{h_d}{H_d} \tag{9}$$

$$f_{2di} = \frac{m_{di}}{M_{di}} \tag{10}$$

d	=	day;
i	=	8-h shift;
j	=	30-min counting period;
Y	=	number of chinook salmon counted;
m	=	number of 30-min counting periods sampled in a shift;
M	=	total number of possible 30 min counting periods;
h	=	number of 8-h shifts sampled;
H	=	total number of possible 8-h shifts;
D	=	total number of possible days;
f_1	=	fraction of 8-h shifts sampled;
f_2	=	fraction of 30-min counting periods sampled;
s_2^2	=	estimated variance of total across counting periods; and,
s_2^1	=	estimated variance of total across shifts.

The abundance of chinook salmon passing the counting tower was then estimated using:

$$\hat{N}_{NR} = \sum_{h=1}^{L} \hat{N}_h \tag{11}$$

$$\hat{V}\left(\hat{N}_{NR}\right) = \sum_{h=1}^{L} \hat{V}\left(\hat{N}_h\right). \tag{12}$$

When *k* consecutive days were not sampled, the moving average estimate for the missing day *i* was calculated as:

$$\hat{N}_i = \frac{\sum_{j=i-k}^{i+k} I(\text{day j was sampled})\hat{N}_j}{\sum_{j=i-k}^{i+k} I(\text{day j was sampled})} \tag{13}$$

where:

$$I(\cdot) = \begin{cases} 1 & \text{when the condition is true} \\ 0 & \text{otherwise} \end{cases} \tag{14}$$

is an indicator function.

The estimate of the daily variation for missed days was the maximum variance of the *k* days before and the *k* days after the missed day *i*.

ABUNDANCE ESTIMATOR: UNALAKLEET RIVER

The number of chinook salmon escaping into the Unalakleet River was estimated by expanding the North River tower count by the proportion of chinook salmon carrying radio transmitters which migrated up the North River:

$$\hat{N}_{total} = \frac{\hat{N}_{NR}}{\hat{P}_N} \tag{15}$$

where:

$\hat{N}_{NR}$ = the number of chinook salmon estimated past the North River tower; and,

$\hat{P}_N$ = the estimated proportion of radio-tagged chinook salmon which moved up the North River.

The variance of the total abundance was estimated using Goodman's (1960) formula for an exact variance of a product:

$$V\left[\hat{N}_{Total}\right] = \left(\frac{1}{\hat{P}}\right)^2 \left(V\left[\hat{N}_{NR}\right]\right) + \left(\hat{N}_{NR}\right)^2 \left(V\left[\frac{1}{\hat{P}}\right]\right) - \left(V\left[\frac{1}{\hat{P}}\right]\right)\left(V\left[\hat{N}_{NR}\right]\right) \tag{16}$$

where:

$V\left[\hat{N}_{NR}\right]$ = variance of the estimate

of chinook passage past the North River tower,

$$V\left(\frac{1}{\hat{P}}\right) = \frac{1}{\hat{P}^4} V(\hat{P}) \quad \text{by the delta method.} \tag{17}$$

ESCAPEMENT PROPORTIONS

The null hypothesis that the proportion of chinook salmon migrating into the North River was the same during 1997 and 1998 was tested by calculating the critical value z as follows (Zar 1984):

$$z = \frac{\hat{P}_1 - \hat{P}_2}{\sqrt{\frac{\overline{PQ}}{n_1} + \frac{\overline{PQ}}{n_2}}} \tag{18}$$

where:

$$\overline{P} = \frac{n_1 \hat{P}_1 + n_2 \hat{P}_2}{n_1 + n_2}; \tag{19}$$

$$\overline{Q} = 1 - \overline{P}; \tag{20}$$

$\hat{P}_1$ = the proportion of radio tagged chinook salmon which migrated up the North River in 1997;

$\hat{P}_2$ = the proportion of radio tagged chinook salmon expected to migrate up the North River in 1998;

n_1 = the number of radio tagged chinook salmon successfully tracked to a spawning area in 1997; and,

n_2 = the number of radio tagged chinook salmon successfully tracked to a spawning area in 1998.

AGE-SEX-LENGTH COMPOSITIONS

Chinook salmon carcasses were collected using long-handled spears from drifting boats. To reach spawning grounds that could not be reached using a jet-powered riverboat, a 10-ft inflatable raft was helicoptered to the confluence of the Unalakleet and Ten Mile rivers. From the mainstem of the Unalakleet River carcasses were collected from the confluence of Ten Mile River to 10 km below the mouth of the North Fork River. From the North River, carcasses were collected from a riverboat (16-ft with a 40-hp jet motor), 3 to 40 km upstream from its confluence with the Unalakleet River. The upper limit of the North River was the furthest point that the riverboat could safely navigate. Carcass samples were taken from the Unalakleet and North rivers during 5-8 August and 10-12 August, respectively.

Data collected from carcasses included the following: date, sex, approximate location, and length (mid-eye to fork-of-tail). Sex was determined from external characteristics and by cutting open the fish and inspecting for residual gametes. Three scales were removed from each fish and placed directly on gum cards (ten fish per card) for age determination. Scales were removed from the left side approximately two rows above the lateral line along a diagonal line downward from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin (Welander 1940). Ages were determined from scale patterns as described by Mosher (1969).

Proportions of female and male chinook carcasses and gillnet catches by ocean age or 25-mm length category and the associated variances were estimated using:

$$\hat{p}_g = \frac{n_g}{n} \tag{21}$$

$$\hat{V}(\hat{p}_g) = \frac{\hat{p}_g(1-\hat{p}_g)}{n-1} \tag{22}$$

where:

$\hat{p}_g$ = estimated proportion of chinook salmon in age or length class g;

n_g = number of chinook salmon in age or length class g; and,

n = total number of chinook salmon sampled.

RESULTS

RADIO TELEMETRY

Three hundred and nineteen chinook salmon were captured in the gillnet from 17 June through 15 July. Catches of chinook salmon averaged 12 fish per day with the highest catch (27 fish) occurring on 24 June (Figure 3).

At the onset of sampling 155 radio tags were to be inserted in chinook salmon. During the course of sampling 12 chinook salmon implanted with radio tags were captured in the commercial fishery and the radio tags were recovered. Ten of these commercially-caught radio tags were in good condition and were reinserted into new fish, while the other two radio tags had severed antennas and were discarded, leaving 153 radio tags to be located. Of these 153 radio-tagged fish, only four were never detected with radio telemetry equipment within the Unalakleet River drainage and were never accounted for in the subsistence, commercial and sport fisheries. It is assumed that these four fish either died (due to handling or predation), regurgitated their transmitters, had malfunctioning transmitters, swam back to the ocean, were captured in the commercial, subsistence, or sport fisheries and not reported, or were never detected upstream. Thus while a total of 165 chinook salmon were implanted with radio tags, 155 total radio tags were depolyed. Ninety (59.9 %; SE = 4.0%) of the radio-tagged chinook salmon swam up the mainstem of the Unalakleet River and 59 (40.1 %; SE = 4.0%) swam up the North River (Table 3). Of the 90 tags that swam up the Unalakleet River, 67 remained in the Unalakleet River, five were found in the North Fork River, 14 swam up the Old Woman River, and four were found in Ten Mile River (Figure 4). Of the 90 tags that migrated up the mainstem of the Unalakleet River, seven radio tags were found within 8 km upstream of the North River confluence where no spawning activity occurs and were confirmed as moralities by ground truthing. It was inferred that these seven fish were destined for spawning areas upstream of the confluence and were used in the calculation of the proportion of fish migrating up the North River. However, the proportions of radio-tagged fish found in the mainstem of the Unalakleet, North Fork, Old Woman, and Ten Mile rivers were weighted by the inverse probability of surviving, or rather, swimming 8 km beyond the mouth of the North River (Table 3).

Weighted and unweighted proportions of fish that swam up the North River were similar, which implies that tags were distributed proportional to run strength (Table 3). Furthermore, there appears to be little evidence of a distinct difference in run timing between the North and Unalakleet River-bound fish (Figure 5). Although it appears that there is a slight delay in the run timing of the North River-bound fish, it is only a delay of 1-2 days. The number of radio-tagged

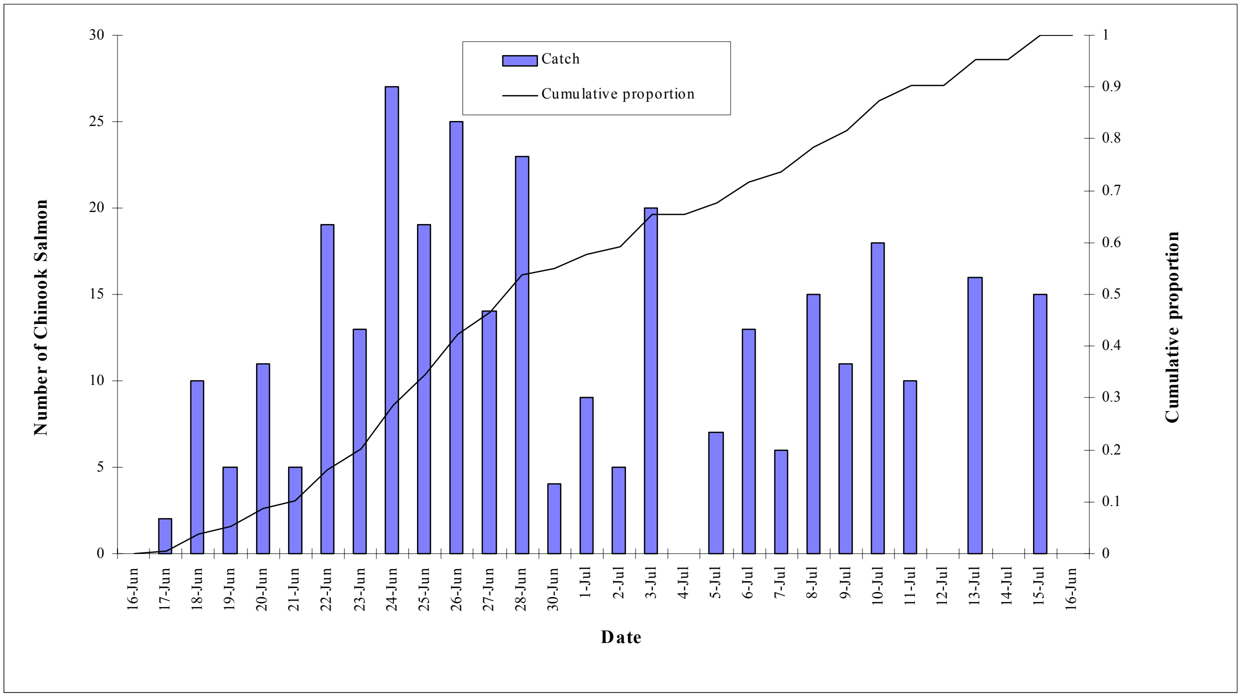

Figure 3.- Daily gillnet catches of chinook salmon during 1998. Days with no catches shown indicate days when no sampling occurred.

Table 3.-Total catch, fishing effort, number of chinook salmon radio tagged, and number of radio-tagged fish located in the Unalakleet River drainage, 1998.

Date	Total fishing effort (min)	Total catch	Number radio-tagged	Number of tracked tags	Tags found in North River	Tags found in Unk.[b] R. drainage	Tags found in Unk.[b] River	Tags found in North Fork River	Tags found in Old Woman River	Tags found in 10-Mile River
17-Jun	80	2	1	1	0	1	1	0	0	0
18-Jun	120	10	5	5	1	4	3	0	1	0
19-Jun	107	5	3	2	1	1	1	0	0	0
20-Jun	216	11	5	4	2	2	2	0	0	0
21-Jun	268	5	3	3	0	3	2	0	1	0
22-Jun	300	19	7	5	1	4	3	0	1	0
23-Jun	262	13	7	4	2	2	2	0	0	0
24-Jun	256	27	12	7	3	4	2	0	2	0
25-Jun	300	19	10	9	1	8	4	2	2	0
26-Jun	300	24	11	11	4	7	6	0	1	0
27-Jun	295	14	7	7	2	5	4	0	0	1
28-Jun	300	23	11	11	6	5	4	0	0	1
30-Jun	266	4	3	3	1	2	1	1	0	0
1-Jul	204	9	7	7	2	5	4	0	1	0
2-Jul	208	5	4	4	3	1	1	0	0	0
3-Jul	209	20	10	10	3	7	6	1	0	0
4-Jul										
5-Jul	233	7	6	6	3	3	3	0	0	0
6-Jul	200	13	8	8	5	3	2	0	1	0
7-Jul	241	6	6	5	0	5	4	0	1	0
8-Jul	300	15	10	8	5	3	2	0	1	0
9-Jul	201	11	6	6	3	3	2	0	0	1
10-Jul	209	18	8	8	3	5	3	0	1	1
11-Jul	195	10	4	4	2	2	2	0	0	0
12-Jul										
13-Jul	213	16	5	5	4	1	1	0	0	0

-continued-

Table 3.-Page 2 of 2.

Date	Total fishing effort (min)	Total catch	Number radio-tagged	Number of tracked tags	Tags found in North River	Tags found in Unk.[b] River drainage	Tags found in Unk.[b] River	Tags found in North Fork River	Tags found in Old Woman River	Tags found in 10-Mile River
14-Jul										
15-Jul	211	15	6	6	2	4	2	1	1	0
Totals	5,694	321	165	149	59	90	67	5	14	4
Unweighted proportion					0.396 (SE = 0.040)	0.604 (SE = 0.040)	0.450 (SE = 0.015)	0.034 (SE = 0.025)	0.094 (SE = 0.025)	0.027 (SE = 0.014)
Weighted proportion					0.401 (SE = 0.040)	0.599 (SE = 0.040)	0.433[a] (SE = 0.015)	0.036[a] (SE = 0.025)	0.101[a] (SE = 0.025)	0.029[a] (SE = 0.014)

[a] Weighted proportions do not include seven fish that were located in the lower mainstem Unalakleet River that were confirmed dead during boat trackings.

[b] Unk. = Unalakleet

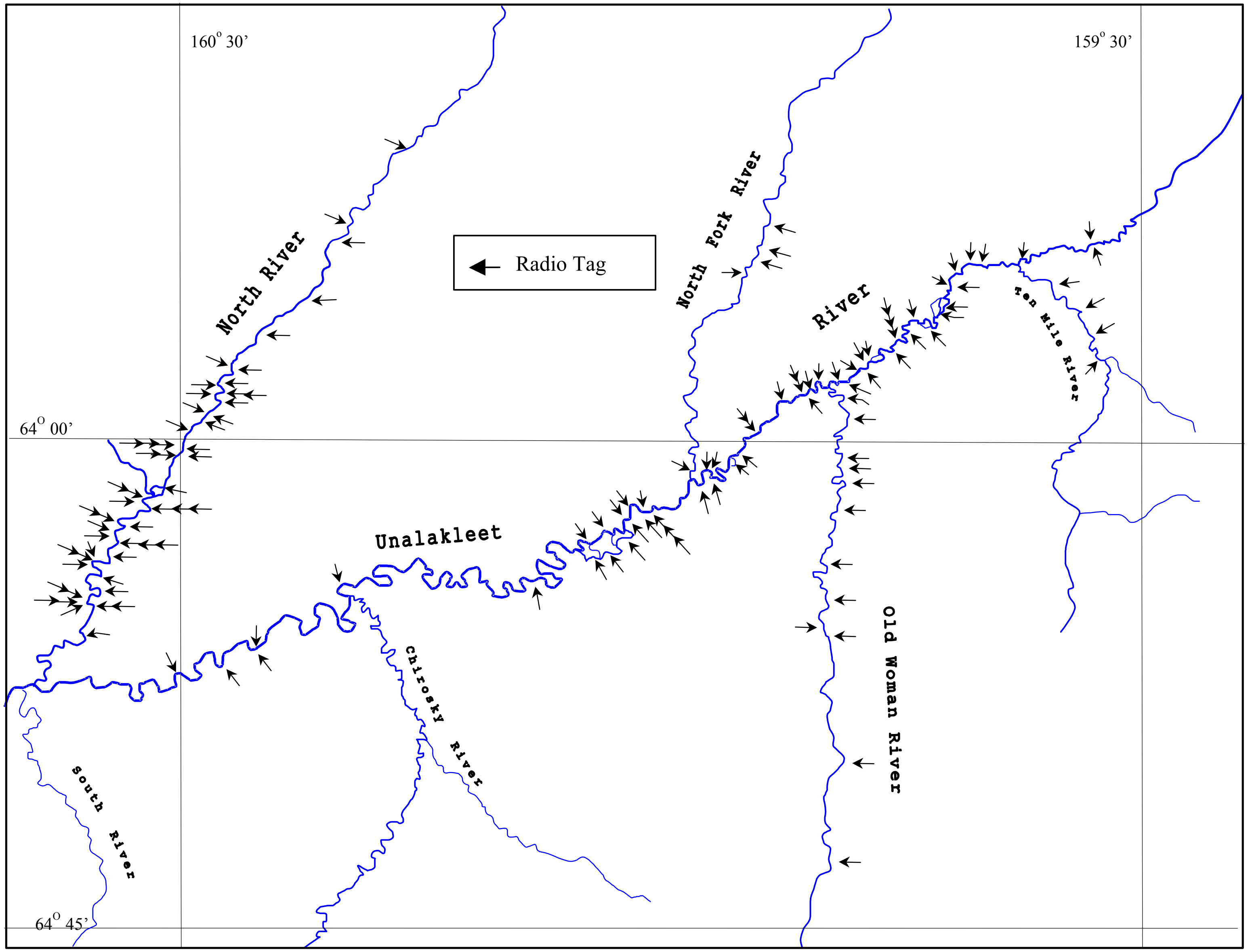

Figure 4.- Location of radio-tagged chinook salmon in the Unalakleet River drainage, 1998.

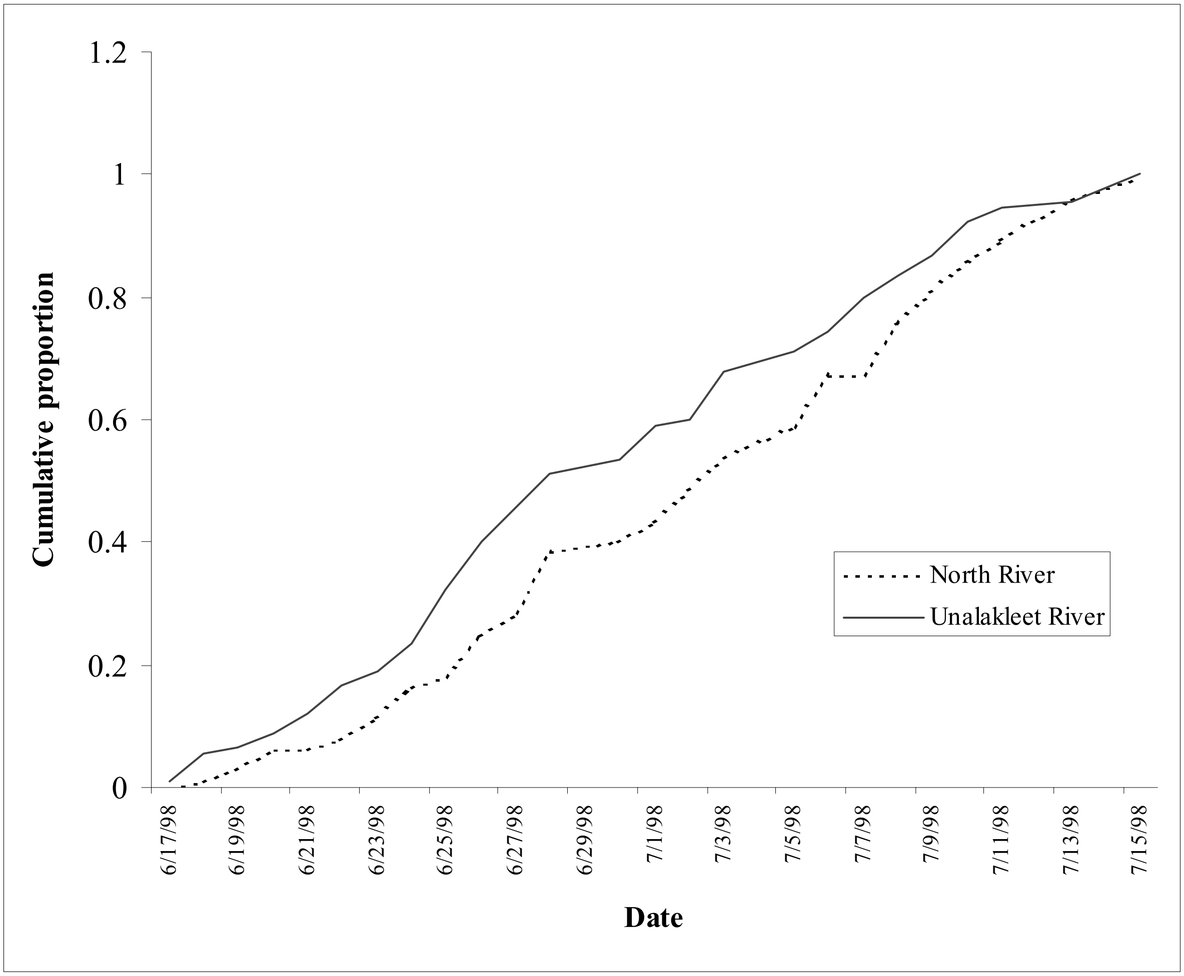

Figure 5.- Cumulative proportion of radio-tagged chinook salmon located in the North and Unalakleet rivers, 1998. Dates indicate the day fish were tagged.

fish located in the North and Unalakleet rivers caught during each quarter of the tagging event were found to be similar (χ^2 = 2.93; df = 3, P= 0.40; Table 4).

Of the 319 chinook salmon captured, 24 chinook salmon with jaw tags were reported being captured in commercial gillnets, 12 of which were implanted with radio tags. Of these 12 fish, none had regurgitated their tags. Twelve chinook salmon with jaw tags were reported as caught in the sport fishery, six of which were implanted with tags. Of these six radio-tagged fish four had regurgitated their tags. All of the radio-tagged sport caught fish were captured upstream of the mouth of the North River, two in the North River and six in Unalakleet River.

ESCAPEMENT PROPORTIONS

The proportion of radio-tagged chinook salmon that migrated up the North River in 1997 (37.2%; SE = 4.0; Wuttig 1998) and 1998 (40.1%; SE = 4.0) differed by 2.9%. The hypothesis that the same proportion of chinook salmon migrated into the North River in 1997 and 1998 failed to be rejected and no significant difference was detected (z = 0.5104, P = 0.61). Given these estimates, a significant difference (α = 0.05) could have been detected if the difference had been greater than 7.8%.

NORTH RIVER TOWER COUNTS AND ESTIMATES OF ABUNDANCE

Water quality factors did not interfere with the counting of chinook salmon from the North River counting tower from 15 July until 3 August. High water from 4 to 8 August prevented counting; after the high water event, only two additional chinook salmon were observed migrating upstream. Therefore, all estimates are germane to the period 15 June to 3 August. A total of 860 chinook salmon were observed passing the North River counting tower from 17 June to 1 August. Peak daily escapement occurred on 30 June with 1,293 (SE = 120) chinook salmon passing by the tower (Figure 6, Table 5). Daily passage tended to be greatest during early morning (04:00-06:00, Figure 7).

Escapement for the North River was estimated at 2,092 (SE = 184) chinook salmon. Escapement for the entire Unalakleet River drainage was estimated at 5,220 (SE = 691).

AGE-SEX-LENGTH COMPOSITIONS

A total of 189 carcasses were collected from the North and mainstem Unalakleet rivers combined. Sex ratios were 0.50 (SE = 0.04) males and 0.50 (SE = 0.04) females, and were dissimilar among the two drainages (χ^2 = 3.92, *df* = 1; *P* = 0.05). Comparison of the North River and Unalakleet River samples showed that the length compositions among males (*DN = 0.14*; *P* = 0.97) and females (*DN = 0.16*; *P* = 0.72) were similar. Ages were determined for 164 (0.87) chinook salmon (Table 6). Proportions of aged males and females were similar to those not aged (χ^2 = 1.21; *df* = 1; *P* = 0.27). Male chinook salmon were mostly of age 1.3 (64%) and females were most frequently age 1.3 (57%).

North River

One hundred fifty-two chinook salmon carcasses were collected from the North River. Ages were determined for 141 fish (93% of the sample). The proportion of male and female chinook salmon were 0.47 (SE = 0.04) and 0.53 (SE = 0.04), respectively. Proportions of aged males and females were similar to those not aged (χ^2 = 0.03; *df* = 1; *P* = 0.86). Male chinook salmon were most frequently age 1.3 (66%), and females were mostly age 1.3 (57%) (Table 7). Lengths

Table 4.-Number of tracked radio-tagged chinook salmon located in the North and Unalakleet rivers captured during each quartile of the sampling event.

Quarter	Date Tagged	Tags found in North River	Tags found in Unalakleet River
1	17 June – 22 June	5	15
2	23 June – 28 June	18	31
3	30 June – 6 July	17	21
4	7 July – 15 July	19	23

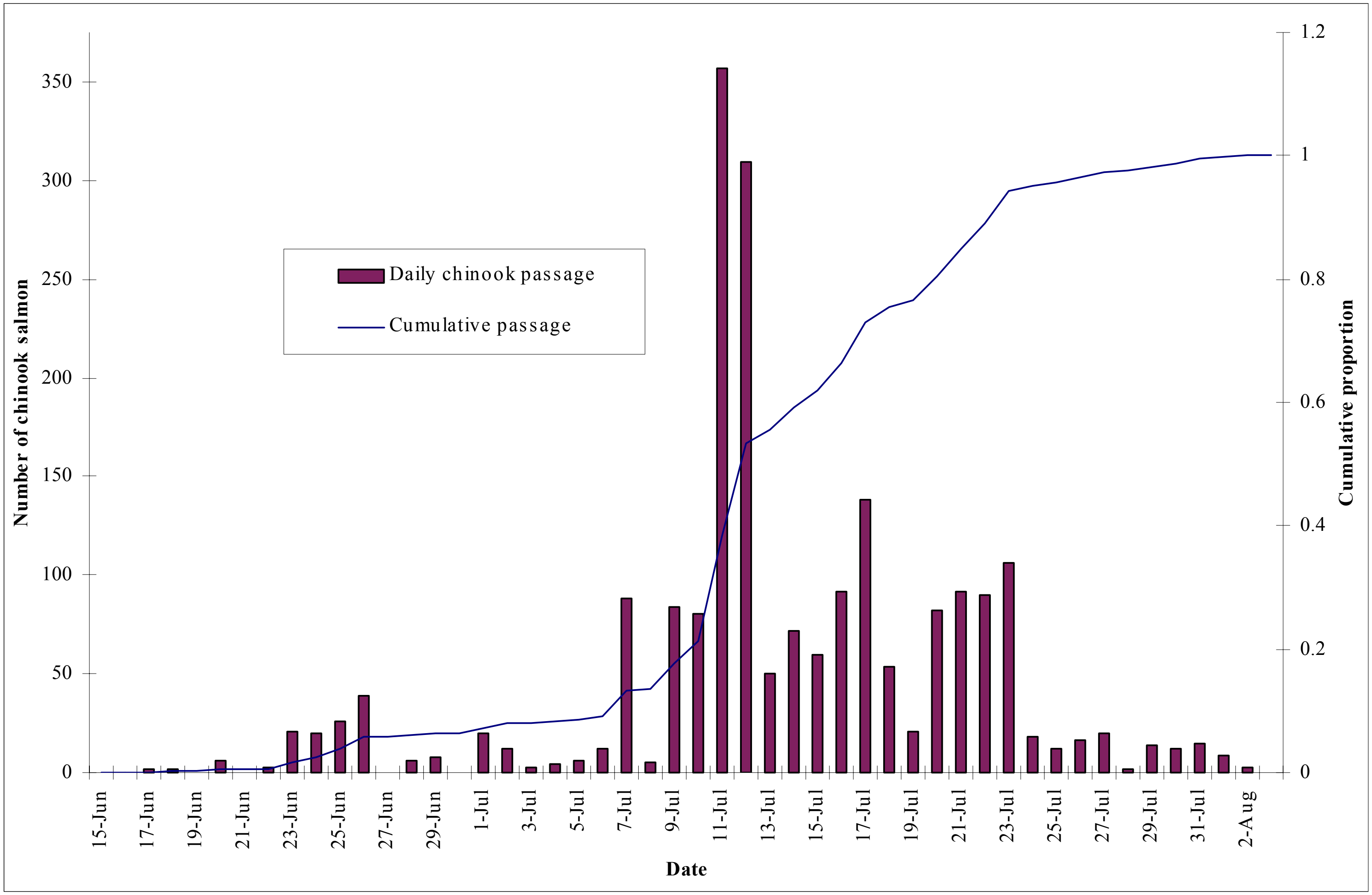

Figure 6.- Daily estimates (expanded counts) of passage for chinook salmon past the North River counting tower, 1998.

Table 5.-Daily counts and estimates of the number of chinook salmon passing by the North River counting tower, 1998.

Date	Count Periods	Count	Expanded Count	SE	Date	Count Periods	Count	Expanded Count	SE
15-Jun	24	0	0	0	10-Jul	24	40	80	7
16-Jun	24	0	0	0	11-Jul	16	119	357	113
17-Jun	24	1	2	2	12-Jul	16	103	309	113
18-Jun	24	1	2	2	13-Jul	24	25	50	6
19-Jun	16	0	0	0	14-Jul	24	36	72	10
20-Jun	16	2	6	6	15-Jul	24	30	60	8
21-Jun	16	0	0	0	16-Jul	24	46	92	12
22-Jun	14	1	3	3	17-Jul	16	46	138	48
23-Jun	22	10	21	12	18-Jul	16	18	54	40
24-Jun	24	10	20	7	19-Jul	16	7	21	9
25-Jun	24	13	26	5	20-Jul	24	41	82	12
26-Jun	16	13	39	12	21-Jul	24	46	92	9
27-Jun	16	0	0	0	22-Jul	24	45	90	10
28-Jun	16	2	6	3	23-Jul	24	53	106	10
29-Jun	24	4	8	2	24-Jul	16	6	18	7
30-Jun	24	0	0	0	25-Jul	16	4	12	5
1-Jul	24	10	20	5	26-Jul	0	0	16	5
2-Jul	24	6	12	4	27-Jul	24	10	20	4
3-Jul	16	1	3	2	28-Jul	24	1	2	3
4-Jul	0	0	5	134	29-Jul	24	7	14	5
5-Jul	8	1	6	134	30-Jul	24	6	12	5
6-Jul	24	6	12	5	31-Jul	16	5	15	5
7-Jul	24	44	88	21	1-Aug	16	3	9	11
8-Jul	18	2	5	8	2-Aug	16	1	3	4
9-Jul	20	35	84	18	3-Aug	8	0	0	0

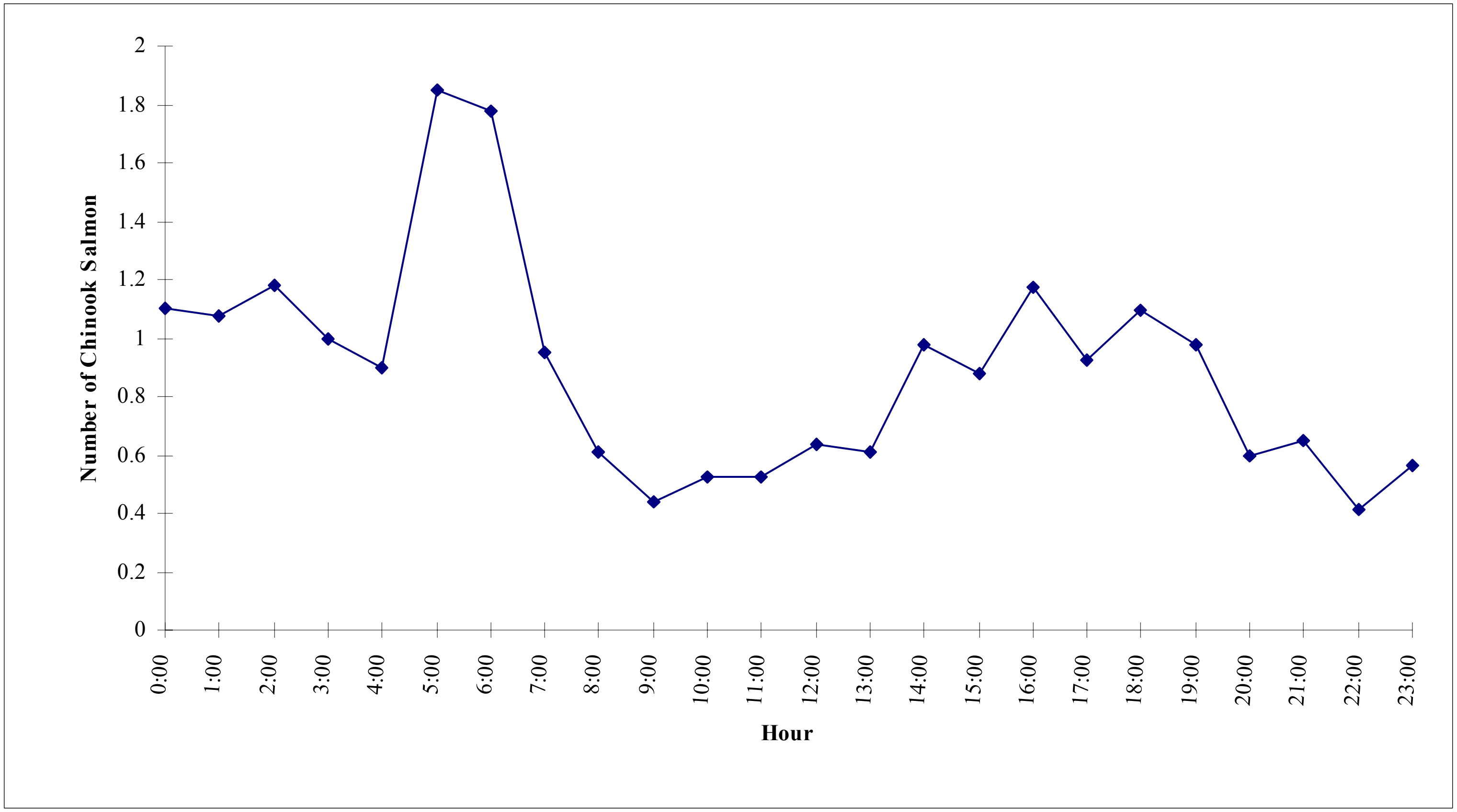

Figure 7.- Average hourly (unexpanded) passage of chinook salmon past the North River counting tower, 1998.

Table 6.-Estimated proportions and mean lengths by age class from carcass samples of male and female chinook salmon in the mainstem Unalakleet and North rivers combined during 1998.

		Sample			Length			
	Age[a]	Size	Proportion	SE	Mean	SE	Minimum	Maximum
Male	1.2	5	0.06	0.03	695	167	465	930
	1.3	54	0.64	0.05	762	79	490	935
	1.4	21	0.25	0.05	800	90	640	935
	2.3	2	0.02	0.02	743	60	700	785
	2.4	3	0.04	0.02	777	93	690	875
	Total	85	1.00					
Total[b]		95	0.50[c]	0.04[c]	755	99	410	935
Female	1.3	45	0.57	0.06	792	46	690	890
	1.4	23	0.29	0.05	820	38	750	900
	1.5	1	0.01		930		930	930
	2.3	3	0.04	0.02	801	69	725	860
	2.4	7	0.09	0.03	803	45	715	840
	Total	79	1.00					
Total[b]		94	0.50[c]	0.04[c]	806	47	690	930

[a] The notation x.x represents the number of annuli formed during river residence and ocean residence (i.e. an age of 1.4 represents one annuli formed during freshwater residences and four years of ocean residence). One annulus is formed each year.

[b] Totals include those chinook salmon not aged.

[c] Proportion and corresponding SE are based on total number (189) of carcasses sampled.

Table 7.-Estimated proportions and mean lengths by age class of male and female chinook salmon carcasses collected from the North River during 1998.

		Sample			Length			
	Age[a]	Size	Proportion	SE	Mean	SE	Minimum	Maximum
Male	1.2	3	0.05	0.03	763	148	645	930
	1.3	41	0.66	0.06	765	70	610	935
	1.4	18	0.29	0.06	811	87	640	935
	Total	62	1.00					
Total[b]		71	0.47[c]	0.04[c]	761	96	410	935
Female	1.3	40	0.57	0.06	793	45	710	890
	1.4	21	0.30	0.06	821	37	750	900
	1.5	1	0.01		930			
	2.3	2	0.03	0.02	840	28	820	860
	2.4	6	0.09	0.03	807	47	715	808
	Total	70	1.00					
Total[b]		81	0.53[c]	0.04[c]	808	45	710	930

[a] The notation x.x represents the number of annuli formed during river residence and ocean residence (i.e. an age of 1.4 represents one annuli formed during freshwater residences and four years of ocean residence). One annulus is formed each year.

[b] Totals include those chinook salmon not aged.

[c] Proportion and corresponding SE are based on total number (152) of carcasses sampled.

were obtained from all 152 carcasses. Male and female chinook salmon averaged 761 and 808 mm, respectively (Figure 8).

Unalakleet River

Thirty-seven carcasses were collected from the mainstem of the Unalakleet River. Ages were determined for 33 fish (89 % of the sample). The proportion of male and female chinook salmon were 0.65 (SE = 0.08) and 0.35 (SE = 0.08), respectively. Proportions of aged males and females were similar to those not aged ($\chi^2 = 3.12$; *df* = 1; *P* = 0.07). Male and female chinook salmon were most frequently age 1.3 (Table 8). Lengths were obtained from all carcasses. Male and female chinook salmon averaged 740 and 795 mm, respectively (Figure 8).

Gillnet

A total of 319 chinook salmon were captured in the gillnet. Sex ratios were 0.55 (SE = 0.04) males and 0.45 (SE = 0.04) females, and were similar among the carcasses collected from the North and Unalakleet rivers combined ($\chi^2 = 1.12$, *df* = 1; *P* = 0.29). Comparison of the gillnet catches and the carcasses collected from the North and Unalakleet rivers combined showed that the length compositions among males (*DN = 0.18*; *P* = 0.30) and females (*DN = 0.19*; *P* = 0.29) were similar. Male and female chinook salmon averaged 767 and 820 mm, respectively. Ages were determined for 293 (0.92) chinook salmon (Table 9). Male chinook were mostly age 1.3 (81%) and females were most frequently age 1.3 (66%).

DISCUSSION

The initial purpose of this project was to estimate the chinook salmon escapement for the Unalakleet River drainage, and successful estimates were attained in both 1997 and 1998. More importantly, in 1998 the proportion of the chinook salmon migrating up the North River was estimated, as in 1997. Attaining these proportion estimates provided some insight on the degree to which these apportionments of Unalakleet River chinook salmon escapement migrating up the North River varies interannually (1997-1998). The proportion of the chinook salmon escapement spawning in the North River in 1997 (37.2%; Wuttig 1998) and 1998 (40.1%) were markedly similar, despite significantly different abundance estimates of 11,204 and 5,220, respectively. This suggests that the North River escapement proportions may vary little and could be used to expand future North River tower counts to provide a reasonable approximation of the Unalakleet River escapements. Clearly, estimating an expansion factor based solely on two year’s data involves inherent risk. Greater precision for an expansion factor would require additional projects that are unlikely given limited resources. Overall, less than half of the Unalakleet River chinook salmon escapement migrates up the North River. This information is consistent with what was assumed by area fisheries managers. Prior to this project, information from aerial surveys suggested that approximately one third to one half of the escapement spawned in the North River (C. Lean, Alaska Department of Fish and Game, Nome, personal communication).

Standardized fishing effort spread equally throughout the entire chinook salmon run was critical to this project. In the initial year of the project, 1997, this was accomplished by fishing a setnet 5-h/d however, higher water conditions in 1998 required the use of a secondary capture technique, driftnetting, to capture chinook salmon for radio tagging. If capture probabilities differed between driftnetting and setnetting, a disproportionate amount of radio tags could be

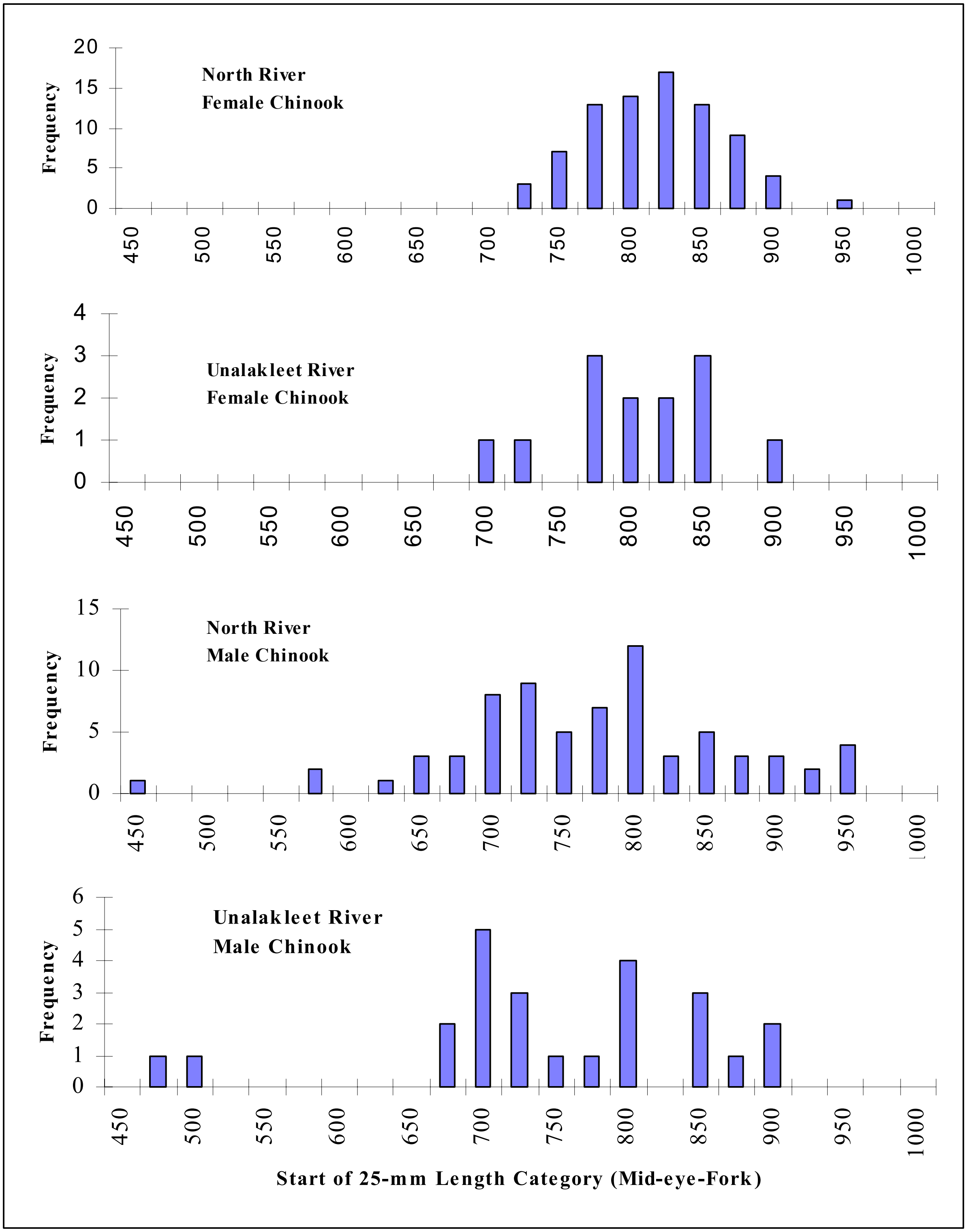

Figure 8.-Length frequency distributions of male and female chinook salmon carcasses collected from the North and Unalakleet rivers, 1998.

Table 8.-Estimated proportions and mean lengths by age class of male and female chinook salmon carcasses collected from the mainstem of the Unalakleet River during 1998.

		Sample			Length			
	Age[a]	Size	Proportion	SE	Mean	SE	Minimum	Maximum
Male	1.2	2	0.09	0.06	593	180	465	720
	1.3	13	0.57	0.11	751	107	490	890
	1.4	3	0.13	0.07	731	96	655	840
	2.3	2	0.09	0.06	742	60	700	795
	2.4	3	0.13	0.07	777	93	690	875
	Total	23	1.00					
Total[b]		24	0.65 [c]	0.08 [c]	740	106	465	890
Female	1.3	5	0.56	0.18	781	57	690	830
	1.4	2	0.22	0.15	810	57	770	850
	2.3	1	0.11		725			
	2.4	1	0.11		775			
	Total	9	1.00					
Total[b]		13	0.35 [c]	0.08 [c]	795	54	690	895

[a] The notation x.x represents the number of annuli formed during river residence and ocean residence (i.e. an age of 1.4 represents one annuli formed during freshwater residences and four years of ocean residence). One annulus is formed each year.

[b] Totals include those chinook salmon not aged.

[c] Proportion and corresponding SE are based on total number (37) of carcasses sampled.

Table 9.-Estimated proportions and mean lengths by age class of male and female chinook salmon captured with a gillnet for radio tagging during 1998.

		Sample			Length			
	Age[a]	Size	Proportion	SE	Mean	SE	Minimum	Maximum
Male	1.3	124	0.81	0.03	734	55	530	900
	1.4	17	0.11	0.03	825	65	680	920
	1.5	1	0.01		875			
	2.3	7	0.05	0.02	782	53	725	870
	2.4	4	0.03	0.01	769	51	705	830
	Total	153	1.00					
Total[b]		172 [c]	0.55 [c]		767	60	530	920
Female	1.3	80	0.66	0.04	806	49	680	945
	1.4	37	0.31	0.04	845	33	765	940
	2.4	4	0.03	0.02	856	22	825	875
	Total	121	1.00					
Total[b]		143[c]	0.45[c]		820	50	680	945

[a] The notation x.x represents the number of annuli formed during river residence and ocean residence (i.e. an age of 1.4 represents one annuli formed during freshwater residences and four years of ocean residence). One annulus is formed each year.

[b] Totals include those chinook salmon not aged.

[c] Proportion and corresponding SE are based on total number of chinnook salmon captured (319).

deployed depending on the capture method used. Inspection of the data suggests that capture probabilities did not differ between driftnetting and setnetting. CPUE for the drift netting was 3.19, compared to 3.58 for set netting. Ideally, a single capture method is preferred. However, given the variable water conditions in the Unalakleet River, an experimental design which calls for the use of strictly a set net to capture chinook salmon may be unrealistic. A more successful sampling design would require a combination of set and drift netting to capture fish, or strictly the use of driftnetting. If a combination of setnetting and driftnetting is used, as in 1998, it is recommended that a single reach of stream is used, the same net is used for both drifting and the set net, and equal fishing effort (soak time) each sampling day is used.

Despite abundance estimates in 1998 being almost half of what they were in 1997, CPUE for the tagging operations in 1998 was greater than in 1997. In 1997 approximately 135 net-h were expended to capture 267 chinook salmon (Wuttig 1998), as compared to 1998 where 95 net-h were required to capture 319 fish. An increase in CPUE from 1997 to 1998 is likely attributed to the water conditions, the use of a slightly different net, and an escapement comprised of larger fish. Water conditions in 1997 were generally clear throughout the sampling events and discharges were below average (M. Scott, Bureau of Land Management, Anchorage, personal communication). In contrast, 1998 discharges were above average with mostly turbid water conditions. Catches tended to be greater during increased discharges and it is suspected that both drift netting and set netting were more effective because the net was less visible and the chinook salmon could not avoid the net. Another factor contributing to the increased catches was the use of a different mesh in the gillnet. The 1998 cable lay twine was finer and tended to catch fish (approximately 710-750 mm) by snagging them on the dorsal whereas the thicker cable lay twine used in 1997 allowed these fish to slip through. The average size of fish captured in 1997 was 832 mm whereas in 1998 it was 791 mm. This is in contrast to the carcass samples collected where the average size of the chinook salmon were smaller in 1997 (684 mm) than in 1998 (791 mm). A standardized net construction is recommended for future projects.

Failure of the remote tracking station during the first half of the chinook salmon run required additional flight time to locate radio-tagged chinook salmon. The mechanism(s) responsible for the failure could not be isolated nor explained. Aerial surveys were successful in locating radio-tagged chinook salmon. The 15-h of flight time was sufficient to locate most of the radio-tagged fish within a 1.6 km radius. More precise locations (within 0.4 km) would have necessitated additional flight time and was not critical to this study. The estimates for the proportion of the chinook salmon escapement migrating up the mainstem of the Unalakleet River, the Chirosky River, the North Fork River, the Old Woman River, and Ten Mile River are suspect because the locations are based on two discrete samples. At the time of the aerial surveys is unlikely that all radio-tagged chinook salmon were at their spawning grounds. It is probable that fractions of the radio-tagged fish were still migrating up stream or had drifted back downstream. Between the two sampling occasions (aerial surveys) one particular fish had drifted from the Old Woman River to the mouth of the North River. In the Taku River, radio-tagged chinook salmon were tracked weekly for up to 16 weeks with multiple receivers and observers to locate 92.5% of the fish that migrated to spawning grounds (Eiler et al. 1991). Burger et al. (1985) utilized boats and/or aircraft every two days to locate radio-tagged chinook salmon in the Kenai River drainage. To minimize the uncertainty of locating fish on their spawning grounds, weekly fights are recommended as opposed to only two sampling occasions.

The 20% upward adjustment of the estimated number of radio tags needed to meet the objective criteria for apportioning the chinook salmon run (150 radio tags) proved to be a conservative and reasonable adjustment. Of the 165 chinook salmon radio tagged, 18 (11%) were captured in both the commercial and sport fisheries. This is contrast to 1997 when only two radio-tagged fish were caught in the commercial fishery and only one was caught in subsistence nets. The increase in radio-tagged fish captured in the fisheries in 1998 can not be explained by differences in capture and handling of fish since methods used were identical to the previous year. Eiler (1991) noted that chinook salmon captured in relatively close proximity to the mouth of their natal streams tended to drop back downstream for longer periods (approximately 1-2 weeks).

Age-sex-length composition estimates attained from carcasses of chinook salmon for the Unalakleet and North rivers are suspect due to possible gear selectivity, timing of the carcass survey, the small sample sizes attained, and behavior. Gear selectivity with carcass sampling may occur due to a person preferentially spearing a chinook salmon carcass based on the visibility, catchability, and attractability (a large fish) of the fish. Timing of the carcass survey is important because male and female chinook salmon may have differing longevity on the spawning grounds. Evenson (1996) found significantly different sex ratios but similar length compositions between two carcass samples collected on the Salcha River. Efforts were made to minimize selectivity on the Unalakleet and North rivers. Timing of the carcass survey was considered be relatively accurate because approximately 80% of the radio-tagged chinook located during carcassing were deceased and available for sampling. Small sample sizes were attained because of turbid waters from a high water event. Water levels remained high and visibility was poor (approximately 6 in) during sampling of the mainstem of the Unalakleet River. The only carcasses collected were those that had been recently deposited onto gravel bars as the water level started to recede. It is likely that more carcasses were available on gravel bars prior to the high water flushing them downstream. During sampling of the North River, visibility improved substantially (approximately 3-4 ft). Despite the improved visibility, chinook salmon carcasses were scarce and it is suspected that most of the carcasses had been flushed downstream during the high water event. Lastly, the proportion of females may be biased high because it has been demonstrated that after spawning, females tend to die near the spawning areas whereas males tend to drift downstream. In the tributaries of the Taku River males and younger fish dominated samples from a carcass weir, females and older fish dominated carcass samples, and estimates from samples taken at live weirs were in between (Pahlke and Benard 1996).

Due to the potential biases associated with carcass samples it is recommended that data attained from the gillnet catches be used for age, sex, and size compositions. The adjusted gillnet catches using established selectivity curves for 8-in mesh used in the Yukon River showed no visible differences when compared to the unadjusted compositions. This suggests that the gillnet captured a representative sample of the chinook salmon escapement in 1998. Had the escapement been dominated by a smaller age class, say 1.2, adjustments to the gillnet catches would have been warranted. Carcass sampling and gillnetting both sampled few age 1.2 chinook salmon.

Poor water clarity in the mainstem of the Unalakleet River has hampered CFD's ability to assess the chinook salmon spawning escapement. The North River counting tower has been operated for eight years (1972-74, 1984-86, and 1996-97), and of these years water clarity has not interfered with the counting and identification of chinook salmon (C. Lean, Alaska Department of Fish and Game, Nome, personal communication). Given the inherent problems associated with aerial surveys, the likelihood of a successful tower count on the North River, and the relatively consistent proportion of chinook salmon that spawned in the North River in 1997 and 1998, an expanded tower count based on the proportion of fish spawning in the North River could provide a reasonable approximation of the Unalakleet River chinook salmon escapement.

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Appendix A

Appendix A-North River counting schedule and hourly counts of chinook salmon during 1998. Numbers indicate a count of salmon during a 30 min period, negative counts indicate movement of fish downstream, and shaded areas indicate hours not counted.

Date	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	Total
15-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17-Jun	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
18-Jun	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
19-Jun									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20-Jun	0	0	0	0	0	0	-1	3								0	0	0	0	0	0	0	0	0	2
21-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0									0
22-Jun	0	0	0	0	0	0	0	0											0	1	0	0	0	0	1
23-Jun	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	3	0	0	0	5			10
24-Jun	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	3	0	1	0	1	3	-1	10
25-Jun	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	1	1	2	2	0	0	1	0	3	13
26-Jun									1	2	2	1	1	0	1	1	0	0	0	0	1	0	0	3	13
27-Jun	0	0	0	0	0	0	0	0									0	0	0	0	0	0	0	0	0
28-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1									2
29-Jun	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	4
30-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1-Jul	0	1	1	1	0	0	0	2	1	0	1	0	0	1	3	0	0	0	0	0	0	0	0	-1	10
2-Jul	0	0	0	2	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	1	0	0	0	6
3-Jul									0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
4-Jul																									0
5-Jul									0	0	1	0	0	0	0	0									1
6-Jul	0	0	0	0	0	1	0	0	-1	0	0	0	-2	0	0	0	1	0	2	0	0	0	2	3	6
7-Jul	0	1	0	0	0	0	0	1	0	0	-1	0	0	0	2	0	12	4	15	2	4	2	2	0	44
8-Jul	0	0	0	0	0	0	0	0	-1	0	0	0	0	0							0	0	2	1	2
9-Jul	0	0	0	1	-3	1	5	5	1	2					2	0	1	4	5	5	1	1	3	1	35
10-Jul	1	3	0	2	2	3	4	2	1	1	0	0	0	1	0	0	4	2	2	2	3	2	1	4	40
11-Jul	4	9	17	10	6	15	18	11					2	1	6	4	12	1	1	2					119
12-Jul	21	10	12	4	10	21	13	4	3	2	1	-1	0	0	3	0									103
13-Jul	0	1	0	1	1	1	0	1	1	2	2	1	1	3	0	0	1	3	2	0	1	1	0	2	25
14-Jul	0	0	1	1	1	0	2	1	2	0	0	3	1	3	6	2	2	3	2	5	1	0	0	0	36
15-Jul	2	1	0	3	2	0	1	0	1	2	0	0	3	1	0	3	1	2	1	3	2	1	0	1	30
16-Jul	1	0	1	1	0	0	0	0	1	1	3	2	1	7	2	2	0	4	3	6	4	4	0	3	46
17-Jul					5	8	10	1	4	0	2	3					1	1	2	1	4	3	0	1	46

-continued-

Appendix A.-Page 2 of 2.

Date	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	Total
18-Jul	0	0	0	0	0	0	0	0					5	1	0	1	0	1	0	10					18
19-Jul	0	0	0	0	0	0	1	0	0	0	1	0	2	0	0	3									7
20-Jul	1	7	5	1	0	5	2	1	2	0	3	1	2	0	1	4	1	2	0	1	0	1	0	1	41
21-Jul	2	2	5	4	3	6	2	1	0	0	2	0	1	2	1	5	3	3	2	2	0	0	0	0	46
22-Jul	4	5	2	1	3	6	4	0	2	0	1	4	5	1	0	2	2	1	0	1	1	0	0	0	45
23-Jul	4	0	1	5	3	6	5	5	2	2	1	3	2	3	6	2	0	0	0	0	1	1	0	1	53
24-Jul									0	0	0	2	0	0	0	2	0	0	1	0	1	0	0	0	6
25-Jul									1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	4
26-Jul																									0
27-Jul	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	1	1	0	0	2	1	1	0	10
28-Jul	0	0	0	0	0	-1	1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	1	1	1
29-Jul	1	0	0	0	1	1	1	1	0	0	1	0	0	-1	1	0	0	0	2	0	0	0	0	-1	7
30-Jul	0	0	0	0	1	1	2	0	0	0	0	0	0	0	1	-1	2	0	1	-1	-1	1	0	0	6
31-Jul									0	0	0	1	1	0	0	1	0	0	0	1	0	0	1	0	5
1-Aug									2	1	0	0	1	0	0	1	0	-2	2	-1	0	1	-1	-1	3
2-Aug	0	0	1	1	-1	0	0	-1									0	0	0	1	0	0	0	0	1
3-Aug	0	0	0	0	0	0	0	0							0										0
Total	42	41	46	39	35	74	71	38	25	18	21	21	26	25	41	37	46	38	45	42	26	26	15	22	860

Appendix B

Appendix B.-Locations of radio-tagged chinook salmon from aerial surveys, 1998. Locations are the furthest upstream location recorded.

Jaw tag #	Date tagged	Length (mm)	Sex	River[a]	Latitude	Longitude
501	17-Jun	730	M	U	63^o 56.71’	160^o 04.51’
503	18-Jun	850	F	U		
506	18-Jun	750	M	U	64^o 02.32’	159 48.97’
694	2-Jul	800	F	N	64^o 00.60’	160^o 29.18’
508	18-Jun	710	F	OW	63^o 56.19’	159^o 49.60’
683	1-Jul	705	M	U	63^o 53.99’	160^o 25.62’
510	18-Jun	765	M	U	64^o 01.43’	159^o 50.76’
510	18-Jun	855	F	N	63^o 56.13’	160^o 35.20’
516	19-Jun	780	F			
518	19-Jun	730	M	N	63^o 59.63’	160^o 30.30’
520	19-Jun	740	M	U	63^o 57.75’	160^o 01.04’
697	3-Jul	680	F	U	63^o 59.61’	159^o 56.24’
522	20-Jun	755	M	N	63^o 54.98’	160^o 36.71’
524	20-Jun	715	F	U	64^o 02.92’	159^o 45.62’
531	20-Jun	825	F	X		
526	20-Jun	730	M	N	64^o 00.58’	160^o 29.45’
529	20-Jun	665	M	U	64^o 02.25’	159^o 47.47’
303	1-Jul	735	M	N	64^o 01.61’	160^o 28.15’
533	21-Jun	870	M	U	63^o 59.63’	159^o 55.97’
648	1-Jul	740	M	N	64^o 00.45’	160^o 29.56’
687	1-Jul	820	M	U	64^o 03.56’	159^o 43.58’
535	21-Jul	720	M	U	63^o 53.10’	160^o 27.96’
538	23-Jun	750	M	X		
686	1-Jul	730	M	U	64^o 01.59’	159^o 51.39’
536	21-Jun	770	M	OW	63^o 58.98’	159^o 48.78’
543	22-Jun	760	F			
539	23-Jun	815	F	N	63^o 57.07’	160^o 34.20’
545	23-Jun	735	M	X		
546	23-Jun	830	M	U	63^o 56.87’	160^o 04.59’
680	30-Jun	835	M			
562	23-Jun	800	M	U	64^o 05.14’	159^o 41.68’
550	23-Jun	735	M	U	64^o 04.55’	159^o 41.97’
551	23-Jun	825	F	OW	63^o 59.54’	159^o 49.26’
689	1-Jul	845	F	OW	63^o 54.32’	159^o 49.73’

-continued-

Jaw tag #	Date tagged	Length (mm)	Sex	River	Latitude	Longitude
614	25-Jun	835	M	U	64° 01.61’	159° 50.56’
698	3-Jul	835	M	U	64° 02.29’	159° 47.15’
553	23-Jun	820	M	U	63° 58.36’	159° 58.49’
557	23-Jun	780	M	N	63° 54.18’	160° 37.00’
700	3-Jul	740	M	U	64° 05.58’	159° 37.86’
830	23-Jun	830	M	X		
561	23-Jun	765	M	U	64° 03.20’	159° 45.9’
692	2-Jul	745	M	N	63° 55.47’	160° 36.44’
566	23-Jun	840	F	N		
567	23-Jun	785	F	X		
570	24-Jun	815	F	X		
572	24-Jun	830	M	X		
688	1-Jul	820	F	U	64° 01.88’	159° 48.79’
695	2-Jul	730	M	N	63° 54.58’	160° 36.35’
574	24-Jun	745	M	OW	63° 57.62’	159° 49.24’
575	24-Jun	825	F	N	64° 01.60’	160° 27.87
579	24-Jun	840	F	U	64° 03.69’	159° 44.84’
580	24-Jun	840	F			
699	3-Jul	725	M	NF	64° 06.22’	159° 54.55
586	24-Jun	805	F	U		
590	24-Jun	880	M	N	63° 56.57’	160° 34.95’
591	24-Jun	740	M	N	63° 55.86’	160° 36.18’
595	24-Jun	795	M	OW	63° 56.26’	159° 49.75’
598	25-Jun	775	M	OW	63° 47.13’	159° 49.63’
599	25-Jun	840	M	U	64° 03.42’	159° 45.34’
619	26-Jun	775	F	N	63° 55.58’	160° 35.61’
600	25-Jun	790	M	NF	64° 06.74’	160° 23.23’
601	25-Jun	900	M	U	63° 52.75’	160° 35.55’
604	25-Jun	735	F	U	64° 01.74’	159° 51.07’
606	25-Jun	830	F	OW	64° 00.95’	159° 48.2’
607	25-Jun	775	M	NF	63° 59.54’	159° 58.25’
610	25-Jun	820	M	N	63° 55.91’	160° 36.07’
679	30-Jun	825	F	NF	64° 06.22’	159° 54.55’
564	23-Jun	830	M	X		
617	26-Jun	850	M	U	63° 52.44’	160° 38.51’

-continued-

Appendix B.-Page 3 of 5.

Jaw tag #	Date tagged	Length (mm)	Sex	River	Latitude	Longitude
618	26-Jun	720	M	N	64° 03.34’	160° 25.04’
620	26-Jun	660	M	U	64° 01.75’	159° 48.72’
621	26-Jun	800	M	OW	63° 57.91’	159° 01.73’
855	26-Jun	855	F	X		
626	26-Jun	905	F	U	64° 04.79’	159° 42.31’
629	26-Jun	855	F	N	63° 57.51’	160° 34.45’
634	26-Jun	765	F	N	64° 04.41’	160° 22.86’
642	27-Jun	830	F	N	63° 55.34’	160° 36.34’
636	26-Jun	815	M	U	64° 00.76’	159° 54.17’
640	26-Jun	870	M	U	64° 03.67’	159° 44.54’
637	26-Jun	845	F	U	64° 04.17’	159° 42.32’
643	27-Jun	860	M	N	64° 01.46’	160° 28.14’
644	27-Jun	840	?	U	64° 03.91’	159° 43.91’
813	15-Jul	775	F	NF	64° 05.72’	159° 54.23’
645	27-Jun	820	F	U	63° 58.65’	159° 56.92’
646	27-Jun	830	F	10	64° 03.34’	159° 32.84’
651	27-Jun	805	M	U	64° 00.79’	159° 54.39’
654	27-Jun	815	F	U	64° 01.75’	159° 52.49’
657	28-Jun	875	F	N	63° 56.50’	160° 35.16’
814	15-Jul	920	M	U	63° 55.99’	160° 08.06’
661	28-Jun	790	M	U	64° 06.24’	159° 34.11’
658	28-Jun	695	M	U	64° 04.79’	159° 42.31’
659	28-Jun	785	M	10	64° 02.48’	159° 32.14’
660	28-Jun	875	M	U	64° 05.96’	159° 33.33’
665	28-Jun	805	F	N	63° 59.59’	160° 31.02’
667	28-Jun	780	F	N	63° 58.81’	160° 31.20’
670	28-Jun	715	M	N	64° 02.39’	160° 27.17’
672	28-Jun	860	F	N	63° 55.97’	160° 35.81’
675	28-Jun	800	F	N	63° 56.06’	160° 35.80’
676	28-Jun	855	M	U	63° 57.83’	160° 04.10’
681	30-Jun	865	F	N	64° 06.26’	160° 21.06’
707	3-Jul	775	M	U	63° 57.18’	160° 03.44’
712	3-Jul	760	M	N	64° 01.16’	160° 28.13’
713	3-Jul	860	F	N	64° 00.50’	160° 29.73’
716	3-Jul	730	M	U	64° 01.72’	159° 50.12’

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Appendix B.-Page 4 of 5.

Jaw tag #	Date tagged	Length (mm)	Sex	River	Latitude	Longitude
815	15-Jul	765	M	N	63° 57.91'	160° 33.33'
718	5-Jul	765	M	U	63° 52.70'	160° 36.80'
719	5-Jul	700	F	U	64° 05.37'	159° 39.90'
720	5-Jul	770	M	U	64° 02.56'	159° 47.58'
727	5-Jul	775	M	N	63° 55.58'	160° 35.61'
721	5-Jul	855	F	N	64° 02.42'	160° 27.89'
726	5-Jul	855	F	N	64° 00.21'	160° 30.14'
730	6-Jul	730	M	N		
731	6-Jul	805	M	U	64° 02.04'	159° 48.35'
732	6-Jul	700	M	N	63° 56.41'	160° 35.55'
733	6-Jul	790	F	N	63° 59.23'	160° 30.88'
739	6-Jul	855	F	N	64° 01.02'	160° 28.72'
734	6-Jul	945	F	U	63° 52.53'	160° 38.05'
735	6-Jul	865	F	OW	63° 55.50'	159° 49.73'
742	7-Jul	830	F	U	63° 53.89'	160° 25.62'
743	7-Jul	815	M			
744	7-Jul	790	F	U	64° 01.67'	159° 51.61'
745	7-Jul	810	F	OW	63° 52.36'	159° 49.60'
729	6-Jul	710	M	N	63° 56.97'	159° 33.50'
746	7-Jul	875	F	U	63° 57.70'	160° 03.04'
747	7-Jul	700?	F	U	63° 57.74'	160° 01.04'
748	8-Jul	755	F	N	64° 01.17'	160° 28.22'
749	8-Jul	830	F	X		
750	8-Jul	790	F	N	64° 06.61'	160° 19.89'
776	8-Jul	775	M	X		
777	8-Jul	755	M	OW	63° 45.51'	159° 51.20'
778	8-Jul	820	M	N	63° 56.063'	160° 35.79'
779	8-Jul	870	F	N	64° 02.78'	160° 27.09'
781	8-Jul	770	M	U	64° 01.35'	159° 52.48'
783	8-Jul	865	F	N	63° 56.99'	160° 35.54'
784	8-Jul	720	M	U	63° 57.91'	160° 02.32'
788	9-Jul	840	M	N	64° 09.22'	160° 16.03'
802	15-Jul	810	F	N	63° 55.47'	160° 36.44'
789	9-Jul	845	F	U	63° 55.85'	160° 19.13'
790	9-Jul	875	F	N	63° 57.07'	160° 34.20

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Appendix B.-Page 5 of 5.

Jaw tag #	Date tagged	Length (mm)	Sex	River	Latitude	Longitude
791	9-Jul	755	M	10	64° 04.90’	159° 35.72’
792	9-Jul	720	M	N	63° 58.64’	160° 32.35’
796	9-Jul	845	F	U	64° 00.82’	159° 53.94’
798	10-Jul	725	M	U	64° 01.61	159° 51.51’
799	10-Jul	840	M	N	63° 58.31’	160° 33.13’
800	10-Jul	780	M	10	64° 04.30’	159° 34.30
751	10-Jul	735	M	N		
770	11-Jul	840	M	N	64° 00.15’	160° 29.85’
753	10-Jul	765	M	U	64° 01.74’	159° 49.58’
763	10-Jul	730	F	N	63° 58.30’	160° 32.13’
701	3-Jul	875	F	U	63° 52.42’	160° 31.65’
764	10-Jul	865	M	OW	64° 01.45’	159° 48.83’
766	10-Jul	765	M	U	63° 58.90’	159° 56.79’
703	3-Jul	880	M	N	64° 01.63’	106° 27.91’
771	11-Jul	790	M	U	63° 57.03’	160° 03.77’
772	11-Jul	840	F	N	63° 57.84’	160° 33.26’
773	11-Jul	850	M	U	64° 05.56’	159° 40.88’
882	13-Jul	755	M	N	63° 57.50’	160° 34.6’
883	13-Jul	710	M	U	64° 02.91’	159° 46.71’
696	2-Jul	880	M	U		
885	13-Jul	825	F	N	64° 00.96’	160° 28.56’
886	13-Jul	800	F	N	64° 00.39’	160° 29.50’
894	13-Jul	765	M	N	63° 56.13’	160° 36.04’
808	15-Jul	815	M	OW	63° 59.38’	159° 48.84’
801	15-Jul	860	F	U	63° 59.00’	159° 57.68’

[a] U represents the mainstem of the Unalakleet River, N is the North River, NF is the North Fork River, 10 is the Ten Mile River, and OW is the Old Woman River. X is a fish caught in the commercial fishery.

[b] Shaded areas indicate no available data.